CLAIMS

What is claimed:

1. A method of fabricating a semiconductor device, having a reduced-oxygen copper-zinc alloy (Cu-Zn) thin film formed on a copper (Cu) surface by electroplating the Cu surface in a chemical solution, comprising the steps of:
providing a semiconductor substrate having a Cu surface;
providing a chemical solution;
electroplating the Cu surface in the chemical solution, thereby forming a Cu-Zn alloy thin film on the Cu surface;
rinsing the Cu-Zn alloy thin film in a solvent;
drying the Cu-Zn alloy thin film under a gaseous flow;
annealing the Cu-Zn alloy thin film formed on the Cu surface, thereby forming a reduced-oxygen Cu-Zn alloy thin film; and
completing formation of the semiconductor device.

2. A method, as recited in Claim 1,
wherein the chemical solution is nontoxic and aqueous, and
wherein the chemical solution comprises:
at least one zinc (Zn) ion source for providing a plurality of Zn ions;
at least one copper (Cu) ion source for providing a plurality of Cu ions;
at least one complexing agent for complexing the plurality of Cu ions;
at least one pH adjuster;
at least one wetting agent for stabilizing the chemical solution, all being dissolved in a volume of deionized (DI) water.

3. A method, as recited in Claim 2,
wherein the at least one zinc (Zn) ion source comprises at least one zinc salt selected from a group consisting essentially of zinc acetate $((CH_3CO_2)_2Zn)$, zinc bromide $(ZnBr_2)$, zinc carbonate hydroxide $(ZnCO_3 \cdot 2Zn(OH)_2)$, zinc dichloride $(ZnCl_2)$, zinc citrate $((O_2CCH_2C(OH)(CO_2)CH_2CO_2)_2Zn_3)$, zinc iodide (ZnI_2), zinc L-lactate $((CH_3CH(OH)CO_2)_2Zn)$, zinc nitrate $(Zn(NO_3)_2)$, zinc stearate $((CH_3(CH_2)_{16}CO_2)_2Zn)$, zinc sulfate $(ZnSO_4)$, zinc sulfide (ZnS), zinc sulfite $(ZnSO_3)$, and their hydrates.

4. A method, as recited in Claim 2,
wherein the at least one copper (Cu) ion source comprises at least one copper salt selected from a group consisting essentially of copper(I) acetate (CH_3CO_2Cu), copper(II) acetate $((CH_3CO_2)_2Cu)$, copper(I) bromide $(CuBr)$, copper(II) bromide $(CuBr_2)$, copper(II) hydroxide $(Cu(OH)_2)$, copper(II) hydroxide phosphate $(Cu_2(OH)PO_4)$, copper(I) iodide (CuI), copper(II) nitrate $((CuNO_3)_2)$, copper(II) sulfate $(CuSO_4)$, copper(I) sulfide (Cu_2S), copper(II) sulfide (CuS), copper(II) tartrate $((CH(OH)CO_2)_2Cu)$, and their hydrates.

5. A method, as recited in Claim 1,
wherein said electroplating step comprises using an electroplating apparatus, and wherein said electroplating apparatus comprises:

(a) a cathode-wafer;

(b) an anode;

(c) an electroplating vessel; and

(d) a voltage source.

6. A method, as recited in Claim 5, wherein the cathode-wafer comprises the Cu surface, and wherein the anode comprises at least one material selected from a group consisting essentially of copper (Cu), a copper-platinum alloy (Cu-Pt), titanium (Ti), platinum (Pt), a titanium-platinum alloy (Ti-Pt), an anodized copper-zinc alloy (Cu-Zn, i.e., brass), a platinized titanium (Pt/Ti), and a platinized copper-zinc (Pt/Cu-Zn, i.e., platinized brass).

7. A method, as recited in Claim 6, further comprising the step of anodizing the copper-zinc alloy to form a thin oxide film in situ using the chemical solution prior to said electroplating step.

8. A method, as recited in Claim 5, wherein said electroplating comprises a plating condition selected from a group consisting essentially of a direct voltage in the range of approximately 1 V to approximately 4 V and a direct current in the range of approximately 0.01 A to approximately 0.2 A.

9. A method, as recited in Claim 5, wherein the Zn-doping in the reduced-oxygen Cu-Zn alloy thin film is controllable by varying at least one electroplating condition selected from a group consisting essentially of:

increasing the at least one zinc (Zn) ion source concentration, thereby slowly increasing said Zn-doping;

increasing the at least one copper (Cu) ion source concentration, thereby slowly decreasing said Zn-doping;

increasing the solution flow rate increases Zn-doping, thereby increasing the pH decreases cathodic efficiency with respect to Zn, and thereby decreasing said Zn-doping;

increasing the electroplating duration, thereby slowly decreasing said Zn-doping;

using a Cu anode, thereby decreasing said Zn-doping;

using a brass anode, thereby increasing said Zn-doping;
increasing the voltage, thereby increasing the Zn-doping; and
increasing the current, thereby increasing the Zn-doping.

10. A method, as recited in Claim 1,
wherein the annealing step is performed in a temperature range of approximately 150°C to approximately 450°C, and
wherein the annealing step is performed for a duration range of approximately 0.5 minutes to approximately 60 minutes.

11. A semiconductor device, having a reduced-oxygen copper-zinc alloy (Cu-Zn) thin film formed on a copper (Cu) surface by electroplating the Cu surface in a chemical solution, fabricated by a method comprising the steps of:
providing a semiconductor substrate having a Cu surface;
providing a chemical solution;
electroplating the Cu surface in the chemical solution, thereby forming a Cu-Zn alloy thin film on the Cu surface;
rinsing the Cu-Zn alloy thin film in a solvent;
drying the Cu-Zn alloy thin film under a gaseous flow;
annealing the Cu-Zn alloy thin film formed on the Cu surface, thereby forming a reduced-oxygen Cu-Zn alloy thin film; and
completing formation of the semiconductor device.

12. A device, as recited in Claim 11,
wherein the chemical solution is nontoxic and aqueous, and
wherein the chemical solution comprises:
at least one zinc (Zn) ion source for providing a plurality of Zn ions;
at least one copper (Cu) ion source for providing a plurality of Cu ions;
at least one complexing agent for complexing the plurality of Cu ions;
at least one pH adjuster;
at least one wetting agent for stabilizing the chemical solution, all being dissolved in a volume of deionized (DI) water.

13. A device, as recited in Claim 12,
wherein the at least one zinc (Zn) ion source comprises at least one zinc salt selected from a group consisting essentially of zinc acetate ($(CH_3CO_2)_2Zn$), zinc bromide ($ZnBr_2$), zinc carbonate hydroxide ($ZnCO_3 \cdot 2Zn(OH)_2$), zinc dichloride ($ZnCl_2$), zinc citrate ($(O_2CCH_2C(OH)(CO_2)CH_2CO_2)_2Zn_3$), zinc iodide ($ZnI_2$), zinc L-lactate ($(CH_3CH(OH)CO_2)_2Zn$), zinc nitrate ($Zn(NO_3)_2$), zinc stearate ($(CH_3(CH_2)_{16}CO_2)_2Zn$), zinc sulfate ($ZnSO_4$), zinc sulfide ($ZnS$), zinc sulfite ($ZnSO_3$), and their hydrates.

14. A device, as recited in Claim 12,
wherein the at least one copper (Cu) ion source comprises at least one copper salt selected from a group consisting essentially of copper(I) acetate (CH_3CO_2Cu), copper(II) acetate ($(CH_3CO_2)_2Cu$), copper(I) bromide ($CuBr$), copper(II) bromide ($CuBr_2$), copper(II) hydroxide ($Cu(OH)_2$), copper(II) hydroxide phosphate ($Cu_2(OH)PO_4$), copper(I) iodide (CuI), copper(II) nitrate hydrate ($(CuNO_3)_2$), copper(II) sulfate ($CuSO_4$), copper(I) sulfide (Cu_2S), copper(II) sulfide (CuS), copper(II) tartrate ($(CH(OH)CO_2)_2Cu$), and their hydrates.

15. A device, as recited in Claim 11,
wherein said electroplating step of said method comprises using an electroplating apparatus, and
wherein said electroplating apparatus comprises:
(a) a cathode-wafer;
(b) an anode;
(c) an electroplating vessel; and
(d) a voltage source.

16. A device, as recited in Claim 15,
wherein the cathode-wafer comprises the Cu surface, and
wherein the anode comprises at least one material selected from a group consisting essentially of copper (Cu), a copper-platinum alloy (Cu-Pt), titanium (Ti), platinum (Pt), a titanium-platinum alloy (Ti-Pt), an anodized copper-zinc alloy (Cu-Zn, i.e., brass), a platinized titanium (Pt/Ti), and a platinized copper-zinc (Pt/Cu-Zn, i.e., platinized brass).

17. A device, as recited in Claim 16,
wherein said method further comprises the step of anodizing the copper-zinc alloy to form a thin oxide film in situ using the chemical solution prior to said electroplating step.

18. A device, as recited in Claim 15,
wherein said electroplating comprises a plating condition selected from a group consisting essentially of a direct voltage in the range of approximately 1 V to approximately 4 V and a direct current in the range of approximately 0.01 A to approximately 0.2 A.

19. A device, as recited in Claim 15,
wherein the Zn-doping (i.e., Zn content) in the reduced-oxygen Cu-Zn alloy thin film is controllable by varying at least one electroplating condition selected from a group consisting essentially of:
increasing the at least one zinc (Zn) ion source concentration, thereby slowly increasing said Zn-doping;
increasing the at least one copper (Cu) ion source concentration, thereby slowly decreasing said Zn-doping;
increasing the solution flow rate increases Zn-doping,
thereby increasing the pH decreases cathodic efficiency with respect to Zn, and
thereby decreasing said Zn-doping;
increasing the electroplating duration, thereby slowly decreasing said Zn-doping;
using a Cu anode, thereby decreasing said Zn-doping;

using a brass anode, thereby increasing said Zn-doping;
increasing the voltage, thereby increasing the Zn-doping; and
increasing the current, thereby increasing the Zn-doping.

20. A semiconductor device, having a reduced-oxygen copper-zinc alloy (Cu-Zn) thin film formed on a copper (Cu) surface, comprising:
a semiconductor substrate having at least one Cu surface formed thereon; and
a reduced-oxygen Cu-Zn alloy thin film formed, by electroplating, and disposed on the at least one Cu surface,
wherein the reduced-oxygen Cu-Zn alloy thin film is formed by annealing a Cu-Zn alloy thin film in a temperature range of approximately 150°C to approximately 450°C, and
wherein the reduced-oxygen Cu-Zn alloy thin film is formed by annealing a Cu-Zn alloy thin film for a duration range of approximately 0.5 minutes to approximately 60 minutes.